MODELLING MAGNETO-RHEOLOGICAL DAMPER USING RADIAL BASIS FUNCTION NEURAL NETWORK

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ABSTRACT

This is a study on modeling the MR damper using RBF. MR damper can be simplify as a damper that using MR fluids. MR fluid contains magnetic particles which will react to current flow when power is supplied. The viscosity of the fluid depends on the current flow. The stiffness of the damper depends on the fluids. This modeling is to achieve the similarity of the results of the experiment using proper machine and apparatus and by using MATLAB software. The data that are obtained from the experiment are used in the MATLAB software to generate graphs. The RBF equations are used in the m-file to get the similarity as the graph from experiment. Comparisons between the graphs are decided by inspection and the most accurate, by using the RMSE graph. The input in m-file is adjusted again and again to get the smallest RMSE as possible.

ABSTRAK

Ini adalah satu kajian ke atas model peredam MR menggunakan RBF. Peredam MR dirigkaskan sebagai peredam yang menggunakan cecair MR. Cecair MR mengandungi zarah-zarah magnetik yang akan bertindak balas ke atas arus elektrik apabila kuasa dibekalkan. Kelikatan cecair bergantung kepada bekalan kuasa. Kekukuhan peredam bergantung kepada cecair. Kemodelan ini adalah untuk mencari persamaan antara keputusan eksperimen yang menggunakan mesin dan peralatan yang betul dan dengan menggunakan perisian MATLAB. Data yang diperolehi dari eksperimen akan digunakan didalam perisian MATLAB untuk menjana graf. Persamaan RBF digunakan didalam m-file untuk mendapatkan persamaan antara graf dari eksperimen. Perbandigan antara graf diputuskan dari pemerhatian dan yang paling tepat adalah dari graf RMSE. Input didalam m-file diselaraskan berulang kali untuk mendapatkan nilai RMSE yang kecil yang mungkin.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

In vehicles suspension system, there are many differences of damping system or suspension system between ordinary cars', four wheel drive vehicles', luxury cars' and other land transports' such as the spring's stiffness, the fluids' stiffness, and more. Imagine that we can control the stiffness during our ride, it will be much more comfortable than usual. One of the methods is by using the magneto-rheological damper.

Magneto-rheological (MR) damper is a damper filled with MR fluids which can simply know as fluid with magnetic particles. This MR fluid will increase its stiffness when there is electrical field. The stiffness will increase as the current increase. MR damper are not restricted just in vehicles' suspension system but they are also used in buildings as to stabilize them during earthquake.

MR damper is a semi-active control device and has been characterized by a set of nonlinear differential equations which represent a model of the MR damper. By using this mathematical model, the force of the MR damper is directly solved to a given displacement and applied voltage. However, solving the non-linear equations describing the performance of the MR damper may be difficult or time consuming to predict a required voltage. Recently, the artificial neural network has been effectively applied to model complex systems because of its great training process.

1.2 PROBLEM STATEMENT

The problem statements of this project are expressed as follows:

i) To use the MATLAB software for modeling.
ii) To get the similar result as an actual MR damper using Radial Basis Function (RBF) method.
iii) The result errors must be small.

1.3 OBJECTIVE OF PROJECT

The objectives of this project are as follows:

i) To model MR damper using RBF method.
ii) To get the similar results as the actual MR damper.
iii) To get the small root mean square errors (RMSE).

1.4 SCOPE OF PROJECT

This project is using MATLAB software to create simulation for modeling the MR damper with Radial Basis Function (RBF) and compared the results between the theoretical and the experimental. Then, the graph behaviors between those two results need to be analyzed whether they are similar or not and to check the RMSE by various input.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will tell more details about Magneto Rheological (MR) Fluids, the uses of MR fluids, types of damping system, design of MR damper.

Magneto-Rheological Fluid or MR fluid as stated by Spencer et. al (1996) is composed of oil and varying percentage of iron particles that have been coated with an anti-coagulant material. When the electricity is inactivated, MR fluid acted like ordinary damper oil (Figure 2.1). When the power is supplied, it will create a magnetic field, micron-size iron particles that are dispersed throughout the fluid align themselves along magnetic flux lines (Figure 2.2). Thus, this will increase the MR fluid's viscosity. MR fluids are effective to control vibrations.

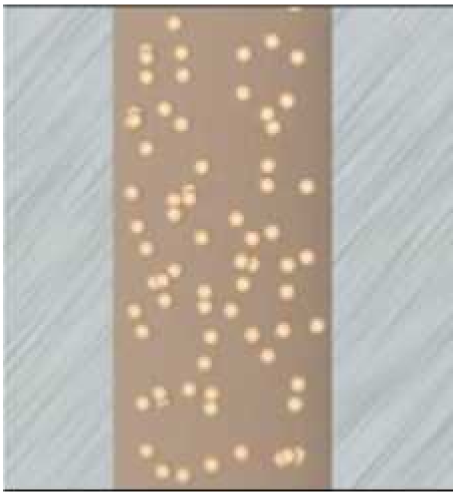

Figure 2.1 : MR Fluid When Power is Not Supply.

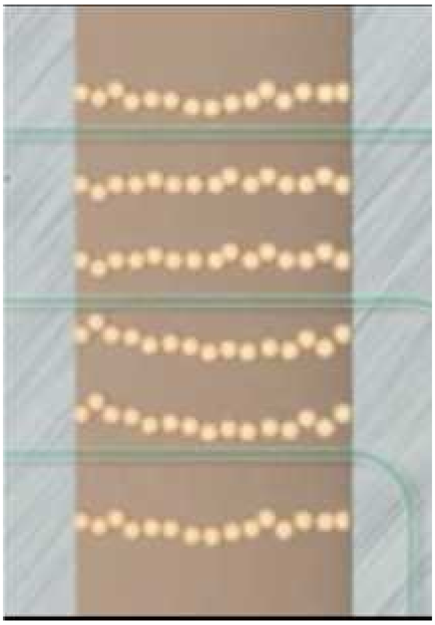

Figure 2.2 : MR Fluid When Power is Supply.

MR fluid can be used in three different ways, all of which can be applied to MR damper design depending on the damper’s intended use. These modes of operation are referred to as squeeze mode, valve mode, and shear mode. A device that uses squeeze mode has a thin film (on the order of 0.020 in.) of MR fluid that is sandwiched between paramagnetic pole surfaces as shown in Figure 2.3. The MR fluid device is said to operate in shear mode when a thin layer (≈ 0.005 to 0.015 in.) of MR fluid is sandwiched between two paramagnetic moving surfaces. Shear mode (Figure 2.4) is useful primarily for dampers that are not required to produce large forces and for clutches and brakes. The last mode of MR damper operation, valve mode (Figure 2.5), is the most widely used of the three modes. MR device is said to operate in valve mode when the MR fluid is used to impede the flow of MR fluid from one reservoir to another. (James, 2001)

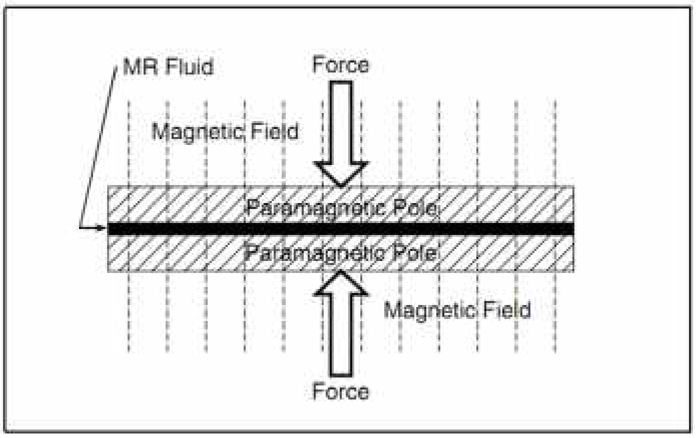

Figure 2.3 : MR Fluid in Squeeze Mode.

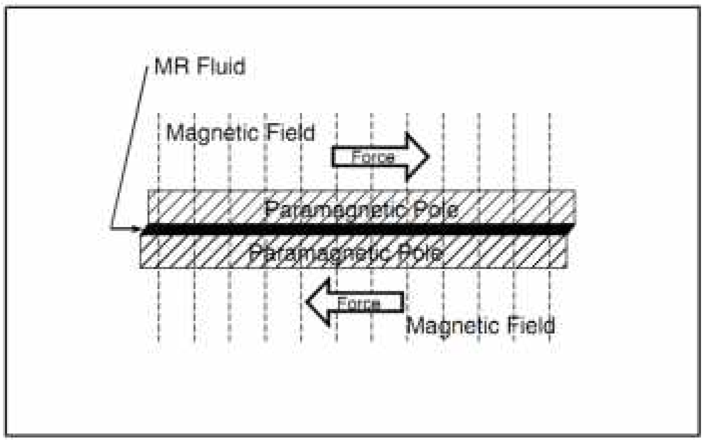

Figure 2.4 : MR Fluid in Shear Mode.

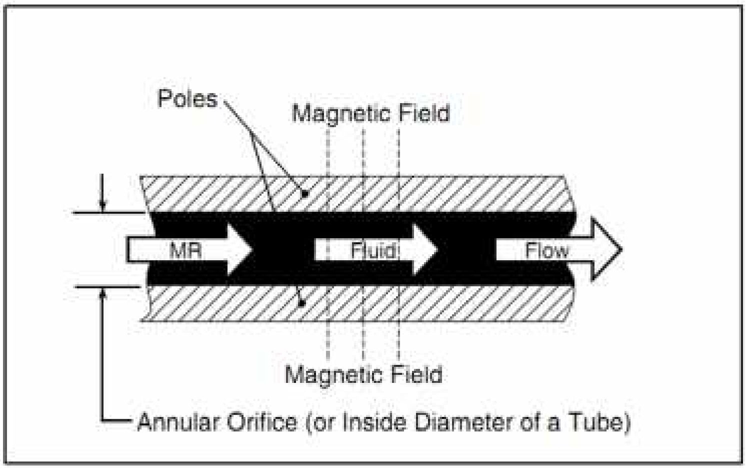

Figure 2.5: MR Fluid in Valve Mode.

Source: James, 2001.

2.2 TYPES OF DAMPING SYSTEM

Ashfak et. al (2009) figured the passive suspension's drawbacks can be overcome by resorting to one of three techniques, adaptive, semi-active or fully active suspension. An adaptive suspension utilizes a passive spring and an adjustable damper with slow response to improve the control of ride and handling. A semi-active suspension is similar, except that the adjustable damper has fast response (about 10 milisecond) and the damping force is controlled in real time. A fully active suspension replace the damper with a hydraulic actuator which can achieve optimum vehicle control, but expensive. Vibration control is becoming increasingly important as the design of mechanisms become more and more precise and less tolerant to transient vibration. Active and semi-active controls provide an important new tool for the control engineer. Transports, buildings, and other have already been design using the active and semi-active damping system.

To simplify, the passive damper system (Figure 2.6) is which the spring is chose base of the vehicle's weight and it using either gas or oit to control the suspension movement. The semi-active (Figure 2.7) system is just like the passive but the damper is controllable and using the MR fluid. On the other hand, the active system (Figure 2.8) is using actuator instead of damper. An actuator is a type of motor for moving or controlling a mechanism or system. It is operated by a source of energy, usually in the form of an electric current, hydraulic fluid pressure or pneumatic pressure, and converts that energy into some kind of motion.

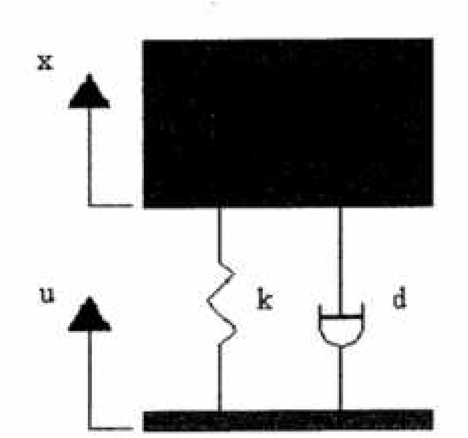

Figure 2.6 : Passive Damping System

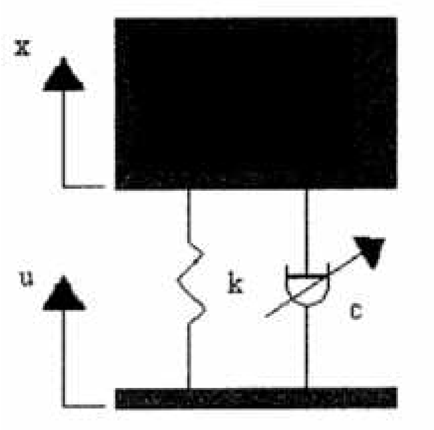

Figure 2.7 : Semi-active Damping System

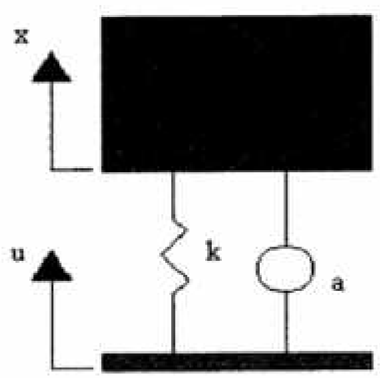

Figure 2.8 : Active Damping System

Source: Ashfak et. al, 2009.

2.3 DESIGN OF MR DAMPER

So far there are known three designs of MR damper. They are monotube MR damper (Figure 2.9), twin tube MR damper (Figure 2.10) and double-ended MR damper (Figure 2.11). A monotube MR damper is one that has only one reservoir for the MR fluid and also has some way to allow for the change in volume that results from piston rod movement. The twin tube MR damper is one that has two fluid reservoirs, one inside of the other. This inner housing is filled with MR fluid so that no air pockets exist. The double-ended MR damper has a piston rod of equal diameter protrudes from both ends of the damper housing. (James, 2001).

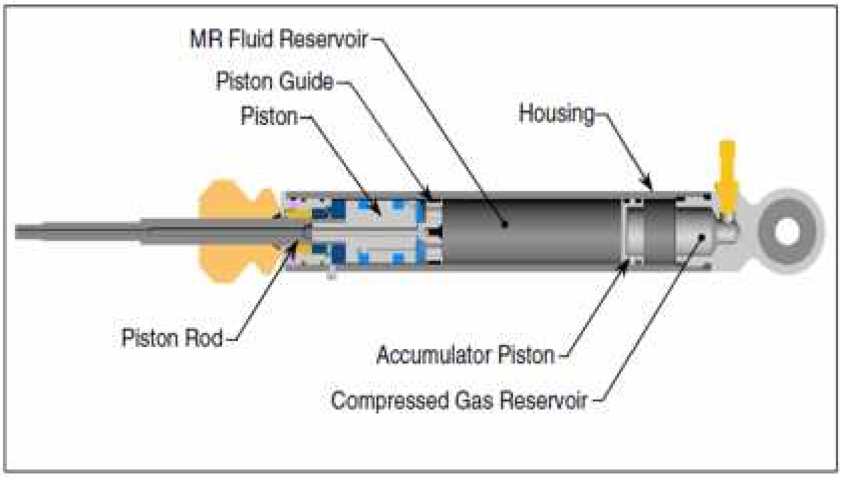

Figure 2.9 : Monotube MR Damper.

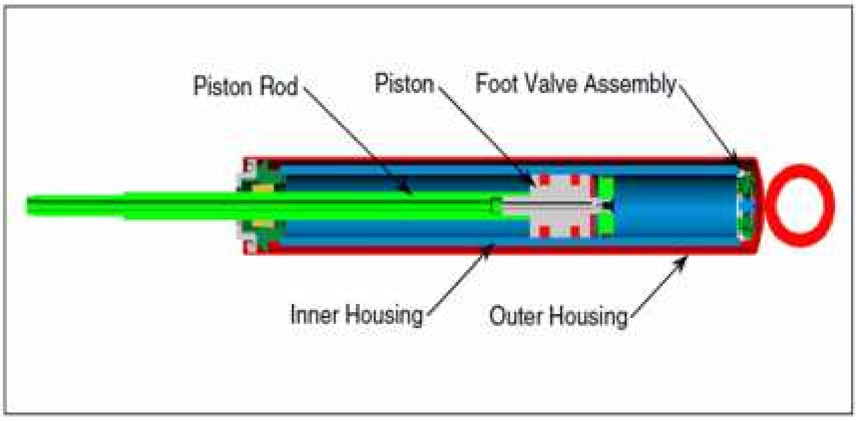

Figure 2.10 : Twin Tube MR Damper.

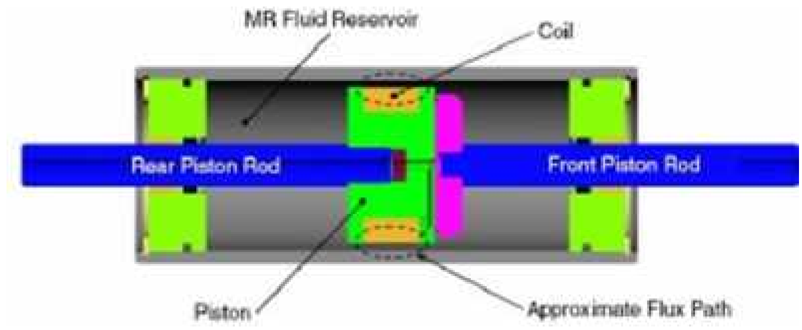

Figure 2.11 : Double-ended MR Damper

Source: James, 2001.

2.4 RADIAL BASIS FUNCTION (RBF) NETWORK

Mark (1996) stated that RBF is a real valued function whose value depends only on the distance from the origin. The basic architecture for a RBF is a 3-layer network, as shown in Figure 2.12. This is becoming an increasingly popular neural network with diverse applications and is probably the main rival to the multi-layered perceptron. Much of the inspiration for RBF networks has come from traditional statistical pattern classification techniques.

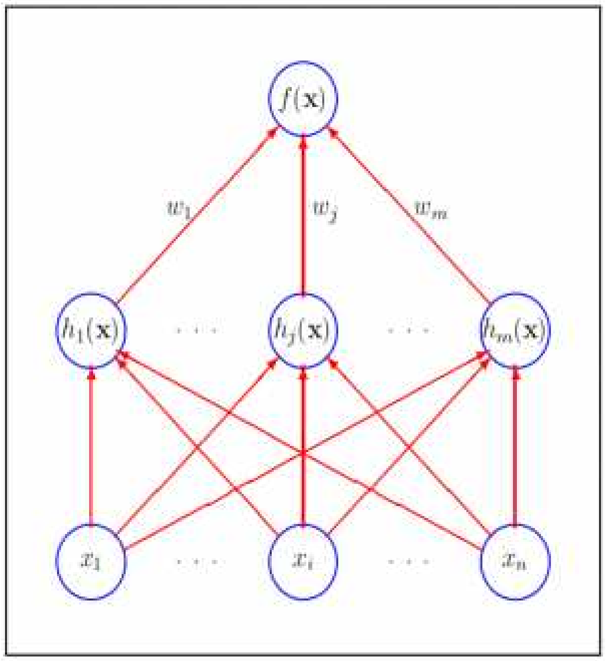

Figure 2.12 : Example of RBF Structure.

Source: Mark, 1996.

An RBF network is nonlinear if the basis functions can move or change size or if there is more than one hidden layer. The single layer networks with functions is focused on which are fixed in position and size. A nonlinear optimisation is used but only for the regularisation parameters in ridge regression section and the optimal subset of basis functions in forward selection section. The kind of expensive nonlinear gradient descent algorithms is avoided such as the conjugate gradient and variable metric methods that are employed in explicitly nonlinear networks. Keep one foot firmly planted in the world of linear algebra makes analysis easier and computations quicker.

Radial functions are special class of function. Their characteristic feature is that their response decreases or increases monotonically with distance from a central point The centre the distance scale and the precise shape of the radial function are parameters of the model all xed if it is linear A typical radial function is the Gaussian which in the case of a scalar input is:

$$h(x) = \exp(-\frac{(x-c)^2}{r^2}) \tag{2.1}$$

Where h(x) is RBF function and x is the input. Its parameters are its centre, c and its radius, r. Figure 2.13 and Figure 2.14 illustrates a Gaussian RBF with centre, c = 0 and radius, r = 1. A Gaussian RBF monotonically decreases with distance from the centre. In contrast a multiquadric RBF which in the case of scalar input is monotonically increases with distance from

$$h(x) = \frac{\sqrt{r^2 + (x-c)^2}}{r} \tag{2.2}$$

the centre (see Figure 2.13), Gaussian like RBFs are local give a significant response only in a neighbourhood near the centre and are more commonly used than multiquadric type RBFs (Figure 2.14) which have a global response They are also more biologically plausible because their response is infinite. (Mark, 1996).

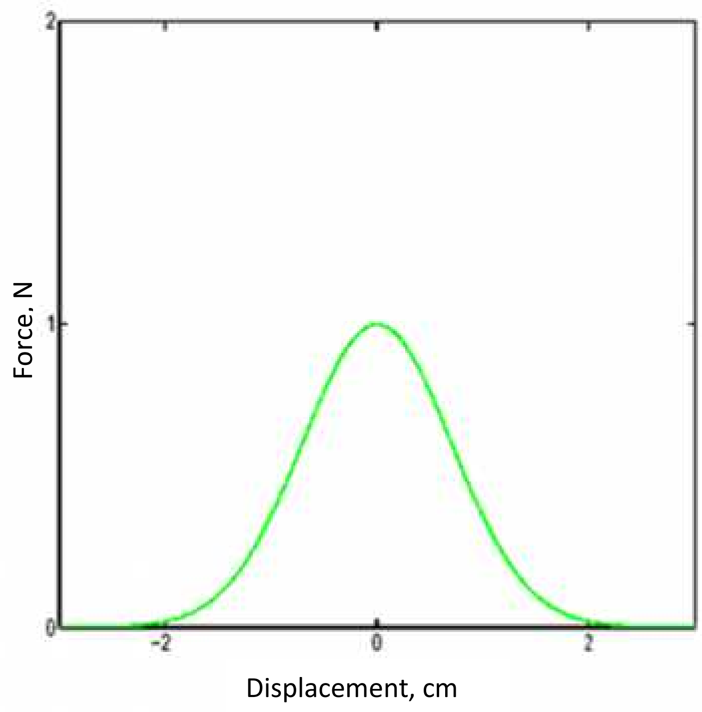

Figure 2.13 : Gaussian RBF

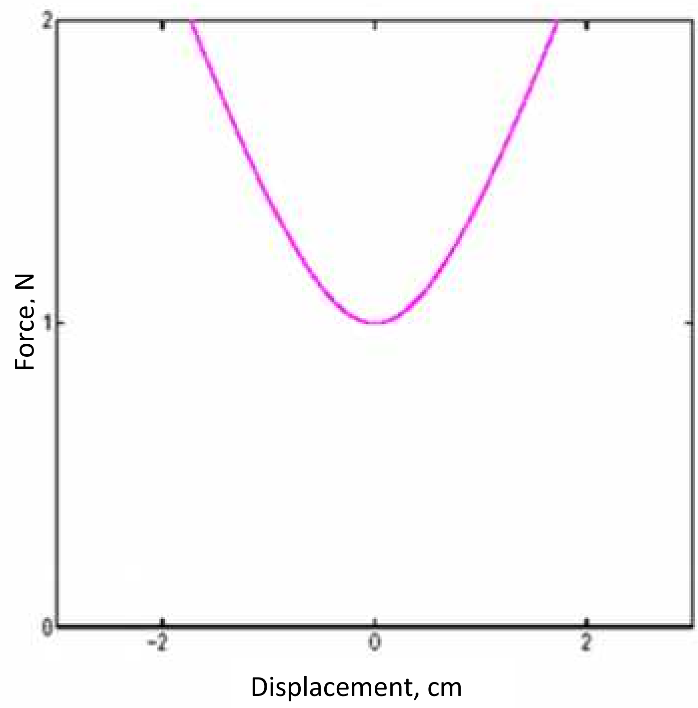

Figure 2.14 : Multiquadratic RBF

Source: Mark, 1996.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This project needs to model the MR damper and get the similar result as an actual MR damper. To do so, it requires modelling and simulating of block diagram by using MATLAB software. There are three things that need to be considering which are the inputs, the outputs and the error.

3.2 FLOW CHART

Flow chart can be considered important because it will guide to do the project properly from the start till the end. The project starts with selecting the project title which is “Modeling Magneto-Rheological Damper Using Radial Basis Function”. The supervisor will give the introduction and discussing about the project. We need to use MATLAB software in this project. Then we need to find the journals for literature reviews and also to find suitable equation based on our method which is Radial Basis Function (RBF).

After getting the result of the simulation, we need to discuss about it with the supervisor so we can know what we are looking for. The process takes plenty of times to get the best result. In Final Year Project 1 (FYP 1), we need to model the MR